

1 TO WHOM IT MAY CONCERN:

2

3 BE IT KNOWN THAT I, JOHN M. POPOVICH, a
4 citizen of the United States of America, residing in
5 Solana Beach, in the County of San Diego, State of
6 California, have invented a new and useful improvement
7 in

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9 ELECTRONIC ASSEMBLY/SYSTEM WITH REDUCED COST, MASS, AND
10 VOLUME AND INCREASED EFFICIENCY AND POWER DENSITY

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BACKGROUND OF THE INVENTION

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3 This application claims priority over
4 provisional application serial number 60/405,826 filed
5 August 26, 2002.

6 This invention relates generally to
7 electronic-optical packages, and more particularly to
8 grids or arrays of such packages supported in such
9 manner as to facilitate their installation and use as
10 in closely assembled or packed configurations.

11 Provisional application serial number 60/405,826 is
12 incorporated herein by reference.

13 Large-scale LED displays are typified by the
14 use of T 1 $\frac{1}{4}$ (5mm) packaged LEDs soldered to rigid
15 printed circuit boards. Such circuit board/modules
16 typically contain a large number of LEDs and must be
17 replaced to correct for the failure of even a single
18 LED. In addition to cost, weight and volume issues or
19 problems, these displays are limited in resolution as a
20 result of the LED package size (typically 0.2 inches in
21 diameter), or about 300 times the plan form area of a
22 bare LED (8000 times the volume), and they are limited
23 in brightness by the small number of LEDs that can be
24 placed in a given area, and also by the thermal
25 resistance of the package and module design. The

1 resolution limit is a function of spacing that is
2 further restricted by package (LED) size. The
3 brightness limit is a function of the number of LEDs
4 per unit area and their individual light output, which
5 is further dependent on the thermal resistance between
6 the LED junction and the local environment. Also,
7 existing LED signage and displays have limited ability
8 to tailor the radiation emission pattern to the needs
9 of the target/audience and thereby increase efficiency.
10 Increased efficiency allows for reduced system and
11 operating cost and/or more radiation delivered to the
12 target.

13 There is need for improvements in LED display
14 assemblies that overcome problems of heating and
15 inability to adequately transfer or dispose of heat
16 generated by LED operation; problems of inadequate LED
17 support on substrates or circuit boards; problems
18 resulting from lack of flexibility of the LED support
19 means; difficulties in manufacturing close packed LED
20 displays; and other problems and difficulties as will
21 appear.

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23 **SUMMARY OF THE INVENTION**

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1 It is a major object of the invention to
2 provide method and means for overcoming the above
3 identified problems. Basically, the improved LED
4 display assembly of the invention comprises:

5 a) an array, forming a grid of electrical
6 conductors,

7 b) light emitting diodes in association
8 with the array and in electrical communication with the
9 conductors that provide power for LED operation,

10 c) the array operable to receive heat from
11 the diodes during diode operation, and the array
12 configured for passing coolant fluid for transfer of
13 heat to the fluid.

14 As will appear, the electrical conductors
15 typically and advantageously may comprise insulated
16 metallic wires which may be interwoven or configured to
17 act as electrical and thermal conductors, and that also
18 may serve as structural supports for arrays of LEDs.
19 The LEDs may be selectively removed or replaced on such
20 supports.

21 It is another object of the invention to
22 provide an LED supporting means, such as a grid
23 characterized by ease of conformance to selected shape,
24 curvature, or complex configuration after the LED array
25 is attached to the grid, the grid having flexibility to
26 enable such compliance to desired shaping.

1 Another object is to provide means to effect
2 and/or guide flow of coolant fluid through or along a
3 shape compliant screen. In this regard, the screen is
4 amenable to fitting to

- 5 i) a substrate on which LED bases are
6 placed, and/or
- 7 ii) a superstrate associated with the
8 screen and LEDs to provide
9 structural strength to the
10 assembly.

11 Yet another object is to provide a first
12 protective sheet facing the diodes to pass light
13 emitted by the diode array; and a second sheet
14 at the opposite side of the screen and diodes, the
15 first and second sheets forming an enclosure within
16 which coolant fluid is flowable. The screen itself may
17 be dark or darkened to increase viewing contrast with
18 the LED array, during its operation.

19 A further object is to provide the electrical
20 conductors to include primary conductors extending
21 generally in one direction, and secondary conductors
22 extending generally in another direction,
23 the LEDs mounted on the primary conductors, and having
24 terminals extending to the secondary conductors for
25 electrical association thereto. In this regard,

1 secondary conductors are typically characterized by one
2 of the following:

- 3 i) substantial spacing therebetween to
4 pass coolant fluid through the
5 screen,
- 6 ii) reduced spacing therebetween, to
7 pass coolant fluid primarily
8 parallel to the screen,
- 9 iii) cross sections which are
10 substantially less than the cross
11 sections of primary conductors
12 which support diodes,
- 13 iv) junctions with diode wires.

14 Yet another object is to provide a screen
15 display incorporating diodes or diode devices, wherein
16 each diode includes a light emitter or emitters, a
17 transparent container having a window area, the emitter
18 supported within the container, and a reflector within
19 the container to reflect emitted light toward said
20 window. As will appear, an electrical lead or leads
21 may extend with helical configuration within the
22 container, such as a glass tube, to the emitter or
23 emitters. The lead or leads may have flattened, or
24 generally rectangular cross sections for stable support
25 of the emitter or emitters.

1 A further object includes provision of a
2 metallic base carrying the container, and through which
3 said lead or leads extend. The base typically has an
4 edge portion defining a recess for reception of a
5 support for the diode, allowing diode rotation about
6 the support. Multiple of the diodes may be supported
7 by a conductor or conductors in a screen, and to have
8 their windows oriented to face in the same or selected
9 directions. The diodes may be rotatable about axes
10 defined by their supporting conductors.

11 Additional objects include provision of
12 certain power providing conductors that comprise first,
13 second, and third pairs of wires to transmit electrical
14 energization to red, green and blue LED pixels,
15 respectively; provision of LED primary, secondary and
16 tertiary wires electrically connected to the red, green
17 and blue pixels, respectively, said primary wire clamp,
18 connected to said first pair of wires, said secondary
19 wire clamp connected to said second pair of wires, and
20 said tertiary wire clamp connected to said third pair
21 of wires; provision of clamped nesting of said primary,
22 secondary and tertiary wires; provision of certain
23 conductors that extend at an acute angle or angles
24 relative to others of said conductors; provision of
25 protector means such as a plate or plate, or a screen

1 or screens at the front or rear of the grid, and with
2 air passing openings, as will appear.

3 These and other objects and advantages of the
4 invention, as well as the details of an illustrative
5 embodiment, will be more fully understood from the
6 following specification and drawings, in which:

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8 **DRAWING DESCRIPTION**

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10 Fig. 1 is a perspective view of one form of
11 the invention; and Fig. 1a is similar but shows coolant
12 flow through the screen;

13 Fig. 2 is a perspective view of another form
14 of the invention, and showing coolant flow primarily
15 adjacent and across the screen and diodes;

16 Fig. 3 is a view like Fig. 2 but showing
17 coolant flow primarily through the screen and past
18 diodes;

19 Fig. 4 is a top plan view of an array of
20 diodes on a screen similar to that of Fig. 1, and
21 showing open spaces between conductors to pass coolant
22 fluids;

23 Fig. 5 is a top plan view of an array of
24 diodes on a screen, similar to that of Fig. 2, the
25 conductors being closely packed;

1 Fig. 6 is a view like that of Fig. 5, but
2 showing a different configuration of electrical
3 conductors;

4 Figs. 7 and 8 are perspective views of two
5 different forms of LEDs;

6 Figs. 9-12 are perspective views of sections
7 of electrical conductors;

8 Fig. 13 shows weaving of electrical
9 conductors;

10 Fig. 14 is an edge view taken on lines 14-14
11 of Fig. 13;

12 Fig. 15 is a perspective view of a ball grid
13 connection to a screen;

14 Fig. 16 is a plan view of a ball grid
15 connection to a screen;

16 Fig. 17 is an elevation showing a ball grid
17 connection to a screen;

18 Fig. 18 is a perspective view showing yet
19 another screen configuration;

20 Fig. 19 is an edge view of the screen of Fig.
21 18; and

22 Figs. 20-23 show arrangements of electrical
23 conductors forming screens, and arrays of LEDs mounted
24 thereon;

25 Fig. 24 is a view showing screen cooling;

1 Fig. 25 is a section taken through an LED
2 package;

3 Fig. 26 is a section taken on lines 26-26 of
4 Fig. 25;

5 Fig. 27 is a view showing a display embodying
6 multiple LED packages of the type shown in Figs. 25 and
7 26;

8 Fig. 28 is a view showing a display embodying
9 multiple LED packages as shown in Figs. 25 and 26, the
10 packages mounted on a conductor screen of the type
11 shown in Fig. 1; and Fig. 28a is a modification;

12 Fig. 29 shows an LED package mounted on a
13 screen conductor and transmitting light to a reflector;

14 Fig. 30 is a schematic diagram of a sign that
15 incorporates the LED supporting grid, and with address
16 wires extending at acute angles;

17 Fig. 31 is a perspective view of a wire
18 bundle;

19 Fig. 32 is a cross section taken through the
20 Fig. 31 wire bundle;

21 Fig. 33 is a section taken on lines 33-33 of
22 Fig. 32;

23 Fig. 34 is a view of protective metallic
24 plate, with air passing openings;

1 Fig. 35 is a section taken through a grid as
2 described, with protective mesh at front and rear sides
3 thereof;

4 Fig. 36 is a view like Fig. 35, showing use
5 of air passing louvers;

6 Fig. 37 is a plan view showing multiple light
7 emitter packages supported by wires, in an array;

8 Fig. 38 is an enlarged view of a portion of
9 the Fig. 37 array;

10 Fig. 39 is a view of two light emitter
11 packages in Fig. 38, but in rotated positions;

12 Fig. 40 is an end view of a connector as
13 shown in Figs. 38 and 39;

14 Fig. 41 is an end view of a conductor conduit
15 supporting conductor wire terminal holders;

16 Fig. 42 is a top plan view taken on lines 42-
17 42 of Fig. 41;

18 Fig. 43 is a perspective view of a conductor
19 wire channel, as also seen in Fig. 41;

20 Fig. 44 is a view showing retraction of
21 conductor wires;

22 Fig. 45 is an enlarged and rotated view of
23 Fig. 42;

24 Fig. 46 is a front elevation showing
25 locations of pixel packages on a fragmentary grid of

1 addressing wires arrayed at 45° relative to conductor
2 wires;

3 Fig. 47 is an enlarged view, like Fig. 44,
4 but taken at the opposite end of the grid;

5 Fig. 48 is a schematic perspective view
6 showing pixel package adjustment rotation about the
7 package axes;

8 Fig. 49 is a schematic perspective view
9 showing pixel package with adjustment rotation capacity
10 about the axis of the package supporting conductor;

11 Fig. 50 shows in schematic form a
12 representative grid having supporting wires or
13 conductors, and pixel packages adjusted at different
14 angles, as for use in a billboard;

15 Fig. 51 is a schematic view showing pixel
16 packages on a grid, and with control electronic
17 circuitry integrated into the packages;

18 Fig. 52 is a schematic view like Fig. 51,
19 with control circuitry in zones or modules at edges of
20 the grid;

21 Fig. 53 is a fragmentary view showing wire
22 conduit wire conduit tensioning;

23 Fig. 54 is a schematic view showing use of
24 bowed end wall mirrors in a pixel package;

25 Fig. 55 is a view like Fig. 54, but rotated
26 90° about the package axis.

DETAILED DESCRIPTION

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3 Fig. 1 shows a screen 10 forming a grid of
4 electrical conductors. As illustrated, the conductors
5 include like primary conductors 11 extending generally
6 in one direction, and designated as an X-direction; and
7 secondary conductors 12 extending generally in another
8 direction, designated as a Y-direction. As shown, the
9 primary conductors preferably have overall diameters d_1
10 or cross sections greater than the overall diameters d_2
11 or cross sections of the secondary conductors, and the
12 latter extend over and under the conductor 11 in a
13 weaving or mesh relationship as at 12a and 12a'. There
14 is space as at 15 between successive parallel
15 conductors 11; and there is space as at 16 between
16 successive undulating conductors 12, whereby coolant
17 can flow downwardly through the screen via spaces 15
18 and 16 and near or adjacent diodes, to remove heat
19 generated by diode operation.

20 Light emitting diodes are located or mounted
21 in an array on various conductors, as shown on crests
22 of conductor 12, and in such manner that each diode is
23 in electrical communication with two conductors,
24 establishing a circuit path from a conductor 11 to a
25 conductor 12, via the diode internal circuit. See

1 conductor energization controls 20 and 21 for two
2 representation diodes 22 and 23, with circuit paths
3 (for diode 22) at 24, 11a, 22, 25, junction 26, 12a,
4 12b and 27; and circuit paths (for diode 23) at 28,
5 11b, 23, 29, junction 30, 12a, 12b, and 29. Controls
6 20 and 29 are interconnected so that diodes 22 and 23
7 can be selectively energized in timed relation. Diode
8 22 is mounted on the top side or crest of conductor
9 11a, and diode 23 is mounted on the top side of
10 conductor 11b. Other diodes as shown are similarly
11 mounted and selectively controlled by controls
12 indicated in bank 31, controls 20 and 21 considered as
13 part of that bank. Electrical connections to metallic
14 wires in the conductors are made by removal of or
15 penetration through conductor insulation. Wires 25 and
16 29 extend in the Y-direction, and may be insulated.
17 Junctions as at 26 and 30 are provided on all crests of
18 secondary conductors 12, and all LEDs are mounted on
19 conductors 11, and protectively between sequential
20 crests of conductors 12.

21 The electrical conductors may comprise
22 insulated metal wires that act as electrical and
23 thermal conductors and that also serve as structural
24 load conductors, for arrays of such diodes. See for
25 example Fig. 9 showing metallic conductor 40 having a
26 square cross section, and a layer 41 of dielectric

1 insulation thereon; Fig. 10 showing metallic conductor
2 42 having tubular cross section with bore 42a, and a
3 cylindrical layer 43 of insulation thereon; Fig. 11
4 showing circular cross section metallic wire at 44,
5 tubular insulation layer 45, tubular cross section
6 metallic wire 46, and tubular layer of insulation 47;
7 and Fig. 12 showing solid metallic wire 48 and
8 insulation 49 thereon, 48 being circular and 49 being
9 tubular. Fig. 7 shows a six-sided LED body 80 with
10 electrical terminal areas 81 and 82; and Fig. 8 shows a
11 similar LED body with terminal areas 83 and 84.

12 Fig. 1a is like Fig. 1, showing an array of
13 LEDs 23 and 24 staggered in the Y-direction at one side
14 of the screen defined by the interwoven conductors 11
15 and 12. Coolant such as air flows at 54, downwardly
16 toward and over the diodes and through the screen
17 defined by spaced conductors 11 and 12. Air may also
18 be caused to flow generally parallel to the screen, as
19 in the X or Y direction, to cool the screen and diodes.
20 Heat generated by the diodes is carried away by coolant
21 flow. Note diode wire junctions 60 with and at the
22 tops of the supporting conductors 12, maximally exposed
23 to coolant flow for heat transfer to coolant. The
24 conductors 11 are large enough in diameter to support
25 the mounted and exposed diodes 22 and 23 and other
26 similar diodes, arrayed as shown.

1 In the forms of the invention seen in Figs. 2
2 and 5, the conductors 11 are generally the same as the
3 conductors 11 in Fig. 1, and are spaced apart as seen
4 at 60. The conductors 12 are arranged in side by side
5 pairs, as seen for example at 12' and 12', and 12'' and
6 12''. Successive pairs of such conductors pass over
7 and under conductors 11, as shown. Like pairs 12'
8 pass together over a conductor 11, along its length,
9 and like successive pairs 12'' pass together over the
10 next conductor 11, along its length in staggered
11 relation in the X-direction in relation to closest
12 pairs 12'; and portions of the pairs 12'' nest between
13 portions of the pairs 12', at locations 62 between
14 conductors 11, as is clear from Fig. 5. A close packed
15 assembly is thereby achieved. As before, LEDs 23 are
16 mounted on exposed tops of sequentially alternate
17 conductors 11b; and LEDs 22 are likewise mounted on
18 exposed tops of sequentially alternate conductors 11a.
19 Each LED has a wire 63 connecting it to the top of a
20 conductor 12 in a pair of such conductors, as at a
21 junction as seen at 64. Insulation is removed or
22 penetrated to enable electrical communication between
23 LED wire 63 and the metal wire within a conductor.

24 In Fig. 2, coolant is shown flowing at 66
25 parallel to the plane of the conductor formed screen;
26 and in Fig. 3, coolant is shown flowing at 67 generally

1 normal to the plane of the conductor formed screen, and
2 through the screen, for removing heat from the LEDs and
3 screen, such heat produced by LED operation. Fig. 3 is
4 generally like Fig. 5, except that the pairs of
5 conductors 12' and 12' are spaced from the pairs 12''
6 and 12'' to form air passing openings.

7 Fig. 4, which is an assembly similar to that
8 shown in Fig. 1, illustrates provision of spaces 66
9 formed between successive straight conductors 11 in the
10 Y-direction, and between undulant over and under
11 extending conductors 12 in the X-direction. Those
12 spaces facilitate flow of coolant fluid through the
13 screen or grid of conductors. The X and Y directions
14 are substantially normal to one another.

15 It will be understood that the screen as
16 shown facilitates its bending or warping, particularly
17 about an axis or axes parallel to the X-direction
18 extents of conductors 11 to conform the screen to
19 desired shape or shapes. This may alter the perceived
20 LED illumination emanating from different portions of
21 the screen, as may be desired.

22 In Fig. 6, the conductors 11 are arranged to
23 extend in spaced parallel relation in the X-direction,
24 as in Fig. 1. Successive conductors 12 are closely
25 packed, so that portions 12a' of conductors 12a closely
26 nest between portions 12b' of conductors 12b,

1 conductors 12a alternating between conductors 12b. LEDs
2 23 are located on the exposed tops of conductors 11b,
3 whereas LEDs 22 are located on the tops of conductors
4 11a which alternate between conductors 11b. Wires from
5 LEDs 22 extend to junctions 26 at the tops of
6 conductors 12b overlying conductors 11b, whereas wires
7 from the LEDs 23 extend to junctions 30 at the tops of
8 conductors overlying conductors 11a.

9 Figs. 13 and 14 show a mesh 90 of interwoven
10 conductors 11 and 12, with LEDs 91 at the crests of
11 conductors 11, which have wave-like configuration, as
12 do conductors 12. This facilitates bending or warping
13 of the screen or mesh about axes extending in both the
14 X and Y direction, to accommodate to desired curved
15 shaping as on object 92. LED wires 91a extend to
16 junctions 94 on conductors 12.

17 Figs. 15 and 16 show a screen or mesh 100,
18 similar to mesh 90 in Figs. 13 and 14, with X direction
19 conductors 101 interwoven with Y direction conductors
20 102. A substrate 103 extends beneath the mesh, and
21 dielectric spacers such as spheres or balls 104 are
22 located between 100 and 103 to engage and position them
23 relative to one another. In Fig. 16, LEDs 106 mounted
24 on crests of conductors 101, have wires 106a extending
25 to junctions 107 on crests of conductors 102.

1 Fig. 17 shows positioning balls 110 between
2 the tops of conductors 12 woven above and below
3 conductors 11. Balls 110 also serve as protection and
4 spacing means. LEDs are mounted on conductors 11
5 between conductors 12. A superstrate 111 may be
6 located at the tops of the balls 110. Superstrate 111
7 may be a transparent plate, to pass light emitted by
8 the LEDs.

9 Figs. 18 and 19 show a mesh 120 similar to
10 that seen at 90 in Figs. 13 and 14. The "'open-weave'"
11 conductors are seen at 111 and 112; and LEDs 113 are
12 mounted on crests of certain conductors such as 111.
13 LED wires 130 extend to junctions 131 on conductors
14 112. The latter may have concentric configuration.

15 Figs. 20-23 show alternative screen and LED
16 configurations.

17 Fig. 24 shows a screen 120 like any of the
18 described screens, with cooling air 121 blown at 122
19 into a space 123 below the screen, to flow adjacent the
20 screen and upwardly through the screen. A housing is
21 seen at 124. Actuators 125 and 126 may be provided to
22 actively and repeatedly displace, deform or warp the
23 screen, as for an active sign display.

24 Referring now to Figs. 25 and 26, the
25 illustrated LED or LED "'pixel'" package, or diode
26 package 150 includes a light emitter or emitters 151

1 within a transparent container, one example being a
2 glass tube 152 having a hemispherical end 152a. A
3 window area 152b is defined by tube 152, or container,
4 for transmission of emitted light in a direction or
5 directions 153. A reflector 154 is located within the
6 tube, and has a reflecting surface 154a for reflecting
7 emitted light in a forward direction 153, through the
8 window and to the exterior. The reflector may have
9 edges 154b engaging or supported by the tube interior
10 wall 152c.

11 An electrical lead or leads indicated at 156
12 extends with helical configuration into the tube and
13 within the tube, to the emitter or emitters, that
14 configuration providing support. The lead or leads
15 preferably has or have a flattened or generally
16 rectangular configuration seen in Fig. 26. Wires
17 contained in the lead or leads may include "'red'",
18 "'green'" and "'blue'" (relating to emitted light
19 color) and an additional wire, such as an electrical
20 neutral or return wire, to the emitter or emitters.
21 The wires may consist of AWC32 copper multifilar and or
22 AWC26 copper wire or AWG26 4 conductor insulated copper
23 multifilar wire helically wound around a rectangular
24 cross-section AWG18 insulated copper wire. A metallic,
25 as for example aluminum base 157, has an edge recess
26 158 receiving the end of the tube 152, and supporting

1 the tube. Specularly reflecting aluminum walls 159 and
2 160 are provided in the tube, and support the reflector
3 154, as at endwise locations 161 and 162.

4 The base 157 defines a through opening 163
5 passing the lead or leads; the base also defines an end
6 recess 164 filled with potting compound 165 as for
7 example epoxy resin. The lead or leads pass through
8 that compound. The base also has an edge portion
9 defining an annular recess 168, for reception of a
10 package support or support portion 169, as for example
11 a portion of the conductor 11a as seen in Fig. 1. The
12 recess 168 preferably has cylindrical wall
13 configuration, allowing rotation of the diode about an
14 axis 170 defined by the recess or conductor. Diode or
15 pixel replacement is also facilitated. Lead wires may
16 be connected to conductors 11 and 12 of the screen, as
17 referred to above.

18 Fig. 27 shows the LED packages 150 of Figs.
19 25 and 26 arranged in a display sequence or
20 configuration. Fig. 28 shows the Fig. 25 and 26 LED
21 packages mounted to mesh defining conductors 11 and 12,
22 so that the LED packages are carried by the mesh
23 conductors 11 and are rotatable about axes 170, as
24 referred to. Integrated pixel electronics is thereby
25 provided. Note leads 156 connected at 156a to
26 conductors 12. Fig. 29 shows LED package 150 mounted

1 on a conductor 11, and transmitting light to a
2 reflector 180.

3 Fig. 30 shows a sign or array employing LED
4 packages as disclosed. The display incorporates
5 vertical conductors 300, with representative addressing
6 wires 301 and 302 extending at acute angles, for
7 example 45° across and relative to wires 300. Wires
8 301 are extensive of wires 302 in a geometric sense.
9 Other addressing wires are indicated in broken lines,
10 as at 302a. LED packages are shown at 303 carried by
11 wires 300. This configuration, shown schematically,
12 achieves reduced lengths of addressing wires, as
13 compared with horizontal wires. Connections 304 and
14 305 to wires 300, 301, and 302a are made at the screen,
15 i.e. array perimeter.

16 Figs. 31-33 are sections showing details of
17 construction of the LED addressing wires which may be
18 of multifilar construction. Referring to Fig. 31, wire
19 301, numerals 306 and 307 refer to LED red light
20 emitting pair; 308 and 309 refer to green emitting
21 pair; and 310 and 311 refer to blue light emitting
22 pair. A pair of red AWG 18 insulated copper wires is
23 used to activate the red LEDs for a row of pixels.
24 This wire pair and its neighboring wire pairs may be
25 helically wound around an insulated central core that
26 may serve as a tensile element. AWG 26 insulated

1 copper wires from the pixel may be nested between wire
2 pairs of like color. An insulated metal retainer may
3 be used to compress the pixel wires against the power
4 supply wires.

5 Numerals 313-315 designate three insulated
6 copper wires from the three pixels, respectively,
7 nested between the referenced wire pairs. A small
8 amount of insulation is removed at wire regions to
9 establish electrical connection between 313 and 306 and
10 307; between 314 and 308 and 309; and between 315 and
11 310 and 311.. A stainless steel retainer 316 extends
12 about the wire assembly, and holds the wires in
13 compression at the central regions, for example as seen
14 at 317, 318, and 319 in Figs. 32 and 33. The retainer
15 may take the form of a split ring fastener that engages
16 the wires 313-315 and may yieldably deform them at
17 their contact points 317-319.

18 Fig. 34 schematically shows a metal plate 316
19 that may be used and positioned as an absorber of
20 sunlight that passes through a display sign array
21 incorporating devices as described above. It also
22 blocks light transmitted toward the rear of the sign
23 array. As such, the plate 316 may be regarded as
24 overlapping the array at the rear thereof. The angled
25 slits 316a that extend through the plate pass cooler
26 air (possibly blower induced) flowing in the space

1 between the plate and the array. Plate 316 also
2 provides mechanical protection at the back of the
3 display. Fig. 34 also represents a side view of an
4 array of overlapping elements that absorb sunlight and
5 extraneous radiation while allowing the passage of
6 cooling air. The array creates a thermal chimney
7 effect to further increase cooling air flow and this
8 effect may be further enhanced by the use of array
9 surfaces with high absorptivity for sunlight and low
10 emissivity in the longwave infrared region. In
11 addition the array provides mechanical protection for
12 signage and display elements.

13 Fig. 35 is a section showing protective
14 metallic screens 317 at the back and front sides of the
15 display array schematically indicated at 318. Such
16 screens may pass cooling air, blower driven at 319.
17 Fig. 36 is like Fig. 35, but shows louvers or slots 320
18 in place of screens 317.

19 Screens may be used in place of circuit
20 boards and conductors on or as film circuitry. Screens
21 can provide power and signal conduits as at 300 or 302
22 in Fig. 30, with reduced cost, mass, and volume, while
23 providing paths between the conduits for flow of
24 cooling fluids to allow systems/products with greatly
25 reduced thermal resistance and/or increased power
26 density operation. Screens may also allow optical

1 communication between circuit elements via open regions
2 between the wires. Screens greatly simplify the
3 manufacture of 3D electronics, allow mechanical
4 compliance, and may behave somewhat elastically to
5 provide pressure type electrical contacts. Screens may
6 have diodes electrically connected to the junctions
7 between crossing wires and/or be in contact with
8 electronic circuitry on chip or chips that provides
9 diodes and/or electrically switchable elements to
10 control the flow of electrons through the screen array.
11 Connection schemes such as solder and including ball
12 grid arrays are also a possible means of connection.
13 Screen and chip arrangements include ''Z Fold''
14 serpentine/sinuous screen with chips between each layer
15 and spiral/helical screens with chips between each
16 layer/rotation. Screens are also good candidates for
17 neural net architectures. Connection with input/output
18 elements may be via ends/edges of screens and employ
19 contact means such as solder, conductive adhesive,
20 and/or mechanical/pressure contact. See 304 and 305 in
21 Fig. 30.

22 Fig. 28a shows modifications in the manner of
23 supporting LEDs and their electrical connections, in an
24 array. The LEDs appear at 500 and are adjustably,
25 and/or removably supported on conductors 501, which may
26 be power conductors, as described in Fig. 25.

1 Addressing wires or conductors, are shown at 502, and
2 may take the multi-filer form as shown in Figs. 31-33.
3 Wires 502 extend at acute angles (for example 45°)
4 relative to conductors 501, extending in direction or
5 directions 504. Coolant gas passing spaces between
6 structure appear at 505. Local electronic circuitry,
7 in the LED packages are seen at 506. Pixel package
8 circuitry is indicated at 507 in the packages. Local
9 addressing wire branches 502a' extend (i.e. branch)
10 from the wires 502 to 156, as described above. Wires
11 502 and conductors 501 form the grid or screen.
12 Linking connectors 540 may be provided as shown to
13 connect successive conductors 501, so as to allow or
14 restrict flexing of the screen or array.

15 Figs. 37-39 show rows and columns of light
16 emitting packages (LEDs) 401 generally of the type
17 referred to above, and supported by conductor wires 402
18 running vertically, in the drawing. Addressing
19 (control) wires appear at 403, and run at acute angles,
20 as for example 45° , relative to wires 402. Wires 402
21 and 403 form a grid, with coolant fluid passing
22 passages 406 through the structure. The packages 401
23 contain internal mirrors 407 and 408 convex toward one
24 another to reflect LED emitted light. Clips 409 are
25 connected to bulges 410 on wires 402, to retain the
26 wires in spaced relation as shown, and to block wire

1 402 rotation about their axes. Fig. 41 is an end view
2 of a clip. The LED packages are electrically connected
3 to wire 402 (that extend through grooves 412 in the
4 bases of the LEDs), and to wires 403, via leads 413.
5 See also circuitry 506 and 507, as described above.

6 Figs. 41-43 show a wire conduit 415, in the
7 form of a metallic channel, for example. It supports
8 or contains closely spaced conductor wires 402a in zone
9 416, and closely spaced addressing wires 403a, in zone
10 417, outside the display or grid, or at the edges of
11 the grid. The items 402a and 403a shown in Fig. 41
12 represent wire cross sections, or wire passing openings
13 in a plastic sheet, or plate, or support 417, carried
14 by the conduit. Numeral 419 may represent a conduit
15 support. See also Fig. 53 showing stabilizing tension
16 springs 420 and 421 connected at 420a and 421a to
17 support 419.

18 Fig. 42, an isometric view, also shows studs
19 422 forming wire terminals carried by conduit 415.

20 Figs. 44 and 47 show conductor wires 402
21 having bends 402b and receiving bosses or retainers
22 425. See also address wires 403 that loop at 403a
23 about retainers 425. A holder 426 extends crosswise of
24 402 to hold them in position. Fig. 45, like Fig. 42,
25 also shows wire bends 402b looping about retainers 425.

1 Retainers 422 also anchor the addressing wires 403,
2 having connections 403a.

3 Fig. 46 schematically shows parallel
4 conductor wires 432 extending vertically, and
5 addressing wires 433 extending at 45° angles relative
6 to wires 432, thereby forming a grid. LEDs i.e. pixel
7 packages 440 are carried by the grid, as described
8 above, and electrically connected to the wires 432 and
9 433. Electronic controls to control the LEDs are
10 indicated at 437. A frame for the grid is shown at
11 438.

12 Fig. 48 schematically shows a pixel package
13 440 peripherally attached to a conductor wire 432, as
14 via an annular groove 440a in 440, allowing adjustable
15 rotation of 440 (see arrows 442) about the package axis
16 443. Fig. 49 shows adjustable rotation of the package
17 440 about the lengthwise axis of conductor 432. See
18 arrows 444. Fig. 50 schematically shows an array 446
19 of LED packages 440, with the packages in different
20 rows having different adjusted angularities, for
21 variably directing emitted light in selected
22 directions.

23 Fig. 51 schematically shows an array 450 of
24 pixel packages 451, which have electronic control
25 circuitry 452 within the pixel envelopes. In Fig. 52,
26 the modified array 450a of LED pixel packages 451a has

1 control circuitry 452a at edges of the array. Array
2 wires 453 and 454 form grids.

3 Figs. 54 and 55 show LED pixel package
4 elements the same as in Figs. 39 and 39. Emitted
5 radiation is within included angle α , in Fig. 5.
6 Azimuth or radiation is reduced by vertical axis
7 parabolic mirror trough, indicated at 460.

8 A preferred form of the invention appears in
9 Figs. 25-33 and Figs. 37-39.

10

11 ADDITIONAL FEATURES

12

13 Large-screen modular displays and signs are
14 enabled, along with various curvatures and complex
15 geometric forms. Also, large scale video displays, and
16 projection displays as for billboards are made
17 possible. Low volume, low mass, low cost, high
18 brightness, high resolution and high efficiency are
19 enabled. Double sided displays can be provided. LEDs
20 can be placed on opposite sides of the screen, and the
21 screen can serve as a pattern for LED placement.

22 LED bases can be placed on a transparent
23 substrate, or the screen can be provided as a polymer
24 film or sheet.

1 Screen and superstrate may collectively
2 provide mechanical, structural strength. Superstrate
3 may be thin or layered to allow second or third flexure
4 modes. Superstrates may be thin to reduce sideways
5 transmission of radiation from LEDs. Some LED sideways
6 light transmission can be provided for integrating
7 between pixels.

8 The invention enables use of means to use
9 conductive/red LEDs. Screen elements can be connected
10 to side faces of LEDs via conductive adhesives, solder,
11 amalgams, indium, stabilite22, and conductive grease.
12 A metallic superstrate can be used.

13 Red LEDs can be provided with two conductors
14 on same side (UEC red on sapphire)

15 Superstrates may have high refractive indices
16 to increase usable radiation (polycarbonate 1.59)

17 Superstrate may have transparent adhesive
18 layer, thermoplastic, thermoset, pressure sensitive

19 The screen can be deformed after weaving,
20 during manufacture, or deform screen before and/or
21 during weaving. Screen warp and woof wires of
22 different metals can be used to reduce the possibility
23 of electrical shorting.

24 Another modification comprises an array of
25 light emitting diodes periodically placed on the weft
26 wires of a woven aluminum and/or copper screen (wire

1 cloth) with the weft wires acting as one conductor, and
2 the warp wires acting as the opposite conductor. The
3 wires may be electrically isolated at their crossing
4 points by such means as anodic coatings and/or by the
5 addition of inorganic or organic over-coatings. The
6 LEDs can be activated by pulsed and/or continuous
7 current and may be addressed as a whole or in groups or
8 individually as in an active video display by control
9 of conductor energization. Woven wire screen provides
10 a very low cost substrate.

11 Additional benefits include efficient heat
12 transport, low mass, low volume, reel to reel
13 manufacturing with screen travel between reels and
14 roll-up on a reel with LEDs placed in position. This
15 allows freedom of display shape, transportable in a
16 roll, ability to be held in tension, in a wide range of
17 materials and sizes.

18 A video display may include an X-Y grid of
19 light emitting diodes placed on an aluminum woven
20 screen suspended or placed between a transparent
21 polycarbonate sheet and another enclosing sheet on the
22 opposite side. An aluminum sheet with gaps between the
23 screen and the enclosing sheet become sufficient to
24 allow forced air to enter and flow upward between the
25 polycarbonate sheet and the screen, through the screen
26 and exiting at the top rearmost part of the screen.

1 Conductor wires act as structural conductors,
2 electrical conductors, and thermal conductors, and may
3 also be provided with a black region made especially
4 effective because of ''cavity effect''. Wires may vary
5 in size, materials, coatings etc. with axis, e.g.
6 stainless steel wire may be used in tension in one axis
7 direction and copper or aluminum wire of smaller
8 diameter may be used in opposite axis direction (i.e.
9 X-Y axes).

10 Manufacture may include placement of a screen
11 on PTFE coated needle/cone array/drum to allow coating
12 of die/wire bond/adhesive attach/screen without
13 clogging holes; then forcing fluid through the screen
14 to prevent clogging. Screens can be spaced apart by
15 use of beads or spheres.

16 Electrostatic or electromagnetic powering of
17 LEDs is possible, and particularly pulsed operation, as
18 with LED video displays. High applied voltage allows
19 smaller conductor cross sections.

20 LEDs with junction faces on metal, or with
21 good junction heat transfer/thermal capacitance, can
22 withstand very high voltage spikes.

23 Patterned superstrate and/or substrate may
24 act as one conductor and screen or substrate as another
25 conductor.

1 Anisotropic screens may be provided with
2 wires along one axis of a different material than wires
3 extending along another axis (thickness, form, alloy.
4 Tensile strength and flexibility may be more important
5 in one axis e.g. opposite roll axis or row axis;
6 dissimilar metals are more apt to form dielectric
7 regions at points of contact and this may be encouraged
8 via processing and/or choice of material properties and
9 coatings; a current flow in one LED row may be
10 several times greater than current flow in another LED
11 row.

12 Advantages and benefits of the Fig. 25 to 28
13 described LED device construction include:

14

15 **OPTICAL**

16 SPATIAL TUNING: Benefits accruing from the
17 ability to aim the radiation from the emitters to the
18 target include a reduction in emitter cost and/or
19 electrical system cost and/or operating cost and/or
20 increased radiation delivered to the target. The
21 OnScreen pixel package can be rotated as for example
22 360 degrees around it's axis and 360 degrees around an
23 axis perpendicular to its' axis, and as a consequence
24 has complete freedom of movement in both elevation and
25 azimuth.

1 HORIZONTAL AXIS OPTICS: The target audience
2 for signage and billboards typically moves horizontally
3 as in vehicles. Horizontal axis optics provide for
4 optimum control as the horizontal angular aperture is
5 typically much greater than the vertical angular
6 aperture.

7 ANGULAR APERTURE CONTROL: Minimizing the
8 radiation beyond the angular extent needed for the task
9 is an important element in minimizing cost. Maximizing
10 the aperture to emitter size ratio allows a
11 minimization of the angular extent of the output
12 radiation. The herein described OnScreen pixel design
13 allows for a minimization of the output radiation by
14 minimizing the emitter array size via close emitter
15 spacing and a narrow gauge substrate and by maximizing
16 the aperture size for a given pixel spacing.

17 BIFACIAL DISPLAY: Bifacial OnScreen displays
18 are possible by the invention, with a single array of
19 bifacial pixels or via a forward and rearward spaced
20 pixel arrays, which may provide or allow differing
21 energizing content to the displays. The OnScreen pixel
22 package allows mounting in front of or in back of the
23 display 'plane'. This allows one face to use pixel
24 packages mounted on the front of the vertical wires and
25 facing forward, and the opposite face to use pixel
26 packages mounted on the opposite side of the wires and

1 facing rearward. The packages may be displaced
2 vertically to allow clearance.

3 TRANSPARENT DISPLAY: OnScreen displays can
4 be made with a wide range of transparency to suit a
5 variety of end uses.

6 OPTICAL EFFICIENCY: The OnScreen pixel
7 design allows for use of a linear emitter array coupled
8 with a visible mirror film parabolic trough, to control
9 radiation in the vertical axis. Horizontal axis
10 radiation may be controlled by end reflectors of
11 similar material and these may be curved to aid in the
12 control of the angular extent of the radiation in the
13 horizontal axis. This design minimizes the average
14 number of reflections and provides for high efficiency
15 for each reflection. The pixel optical system may be
16 contained within a cylindrical glass envelope for
17 environmental protection. Additional benefits of such
18 an envelope include:

19 1) functioning as a circular compressive
20 element to constrain the elastically deformed 3M VMF
21 and thereby cause it to form a parabolic curve; (The
22 film is typically specularly reflecting film such as 3M
23 visible mirror film. The reflecting film may be paired
24 with/attached to additional film/s to provide the
25 desired mechanical and other properties. The film/s
26 may also be adhered to the container walls and/or

1 constrained by lands/ridges/bumps along the container
2 walls.)

3 2) functioning as a container for a wide
4 range of liquids, gels, solids, and/or smaller
5 containers;

6 3) functioning as a refractive optical
7 element.

8 CONTRAST RATIO: Increasing the contrast
9 ratio allows an improvement in visibility and/or a
10 reduction in radiative power for a given visibility.
11 The herein described OnScreen configuration allows high
12 contrast ratio viewing by:

13 1) Minimizing the angular extent of the
14 output radiation and increasing the aperture area of
15 the output radiation reduces the probability of
16 sunlight or other extraneous radiation being reflected
17 from the OnScreen 'display' to the target/viewer,

18 2) Optical porosity (low solidity), which
19 allows a portion of the radiation that would impinge on
20 and possibly be reflected into the target on a high
21 solidity display pass through and be absorbed on a
22 subsidiary surface/s,

23 3) Insuring all surfaces within the targets
24 field of view have very low reflectivity by means such
25 as coating and texturing.

1 DETECTOR/DETECTOR ARRAY: OnScreen and/or the
2 described pixel may also operate as detectors, alone or
3 in conjunction with emitters.

4

5 **THERMAL**

6
7 The lifetime and efficiency of semiconductor
8 devices (LEDs) degrades strongly with increasing
9 temperature. The invention allow for reducing the
10 thermal resistance between the emitters and the local
11 environment, and thereby increases lifetime,
12 reliability, durability, and efficiency and reduce
13 operating cost, pursuant to the following:

14 1) A low solidity array which allows a
15 portion of the solar load to be diverted to subsidiary
16 surfaces and thereby make a smaller contribution to
17 array heating. In addition, the open design allows
18 airflow in and around the array and in very close
19 thermal communication with the emitters.

20 2) Wind enhanced cooling. A porous array
21 allows the passage of and the ability to transfer heat
22 to the local air stream. Wind speed increases strongly
23 with increasing height and high mounted signage and
24 displays may benefit greatly from this cooling.

25 3) Thermally induced convection cooling
26 caused by the wire array, the pixel packages, and by

1 proper design of subsidiary surfaces behind the array
2 (horizontal axis overlapping slats/louvers).

3 4) Solar assisted cooling may be promoted
4 by proper design of subsidiary louvered absorber array
5 behind the screen. Louver surfaces with a high
6 absorptivity for sunlight and a low infrared emissivity
7 may be used to further increase airflow.

8 5) The OnScreen pixel package enables use
9 of a rectangular copper substrate for LED mounting.
10 This substrate acts as a thermal, electrical, and
11 structural conduit and its cross section may be easily
12 sized to provide sufficiently low thermal resistance.
13 The pixel package is thermally coupled to the row and
14 column wires to aid in the transport of heat to the
15 local environment. In addition, the pixel package may
16 be liquid filled to allow reduced LED operating
17 temperature.

18 6) Active cooling may be used if necessary,
19 but its need and its cost may be greatly reduced by the
20 aforementioned features.

21

22 ELECTRICAL

23

24 The invention enables use of active and/or
25 passively addressed pixels. Local (pixel based)

1 electronics may be included in the pixel package and
2 placed on the emitter substrate, behind the reflector,
3 in the aluminum bushing and/or in the hemispherical
4 cap. Local electronics may vary with application and
5 include capacitors, resistors, inductors, diodes,
6 transistors, standard integrated circuits such as 555
7 timers or application specific integrated circuits.
8 Multiplexing may be used to reduce the cost of the
9 electrical system, and the ability to multiplex is
10 greatly increased by minimizing the pixel output
11 radiation required by means discussed in the above
12 optics section.

13 The invention provides for use of in-field
14 replaceable pixels that may be made to be replaceable
15 from either side of the screen.

16 The invention allows for use of vertically
17 oriented column/common wires and 45 degree oriented
18 row/addressing wires to allow large scale seamless
19 signage and displays with all pixels/electronics
20 addressable/accessible from the top or the bottom of
21 the screen.

22 Control electronics may be integrated into
23 pixel packages; and/or control electronics may be
24 concentrated in modules or zones at edge or edges of
25 the arrays.

MECHANICAL/STRUCTURAL

The invention allows for use of robust OnScreen signage/displays created by arranging a parallel array of large diameter vertically oriented common/column wires in tension between horizontal upper and lower rigid members. The upper end of each vertical wire may be formed into a loop and affixed to and electrically isolated from the upper rigid horizontal member. The lower end of each vertical wire may be formed into a loop and elastically attached to and electrically isolated from the lower rigid member by a stainless steel extension spring. Both upper and lower mounts may serve to prevent rotation of the vertical wires around their own axes. A parallel array of 45 degree row wires may be connected in tension between the upper and lower rigid horizontal members by means analogous to those described for the vertical wire array. The 45 degree row wires may be constructed of a large diameter electrically insulated central wire helically wound with a 6 strand small diameter multifilar insulated wire array. The multifilar wire array includes paired red, green, and blue wires. The 45 degree wire array may be placed behind the vertical wire array and the pixel packages may be mounted in

1 front of the vertical wires. The pixel packages may be
2 mechanically connected to the vertical wires by plastic
3 deformation of the pixel package aluminum bushing
4 and/or the wire and/or by adhesives. The pixel common
5 wire may be electrically connected to the large
6 diameter vertical common wire through the aluminum
7 bushing via wirebonding or pressure welding or directly
8 to the larger diameter wire by soldering or pressure
9 type connection. Red, green, and blue wires emanating
10 from the pixel may be connected to the 45 degree row
11 wires by soldering or by pressure type contacts.

12 The row and column wires may be constructed
13 of aluminum to reduce cost and weight for a given
14 strength, electrical and thermal conduction. In
15 addition, electrically insulative coatings adhere
16 better and have longer life on aluminum than copper.

17 OnScreen signage and displays of simple or
18 complex face or form (circular or hyperbolic cylinders,
19 cones and conoids, hyperbolic paraboloids) may be
20 assembled on site or shop fabricated by simple
21 techniques that lend themselves to manual or automated
22 fabrication.

23 Important advantages of the invention are
24 listed as follows:

25 1. Organic Light Emitting Diodes: (OLEDS)
26 may be used as light emitters alone or in conjunction

1 with inorganic LEDs. OLEDs may be easier to apply to
2 screen type substrates and may allow reduced product
3 cost.

4 2. Multiplexing: The ability to tailor the
5 angular extent of the radiation output and the
6 increased contrast provided by the OnScreen design
7 allows a greater degree of multiplexing and a
8 concurrent reduction in system cost.

9 3. 45° Scanning: 45° scanning reduces line
10 artifacts compared to vertical or horizontal scanning
11 and thereby allows higher apparent resolution for a
12 given number of pixels and/or a reduced number of
13 pixels for a given apparent resolution.

14 4. In Field Pixel Replaceability: The
15 ability to replace individual pixels in the filed
16 allows reduced maintenance cost.

17 5. Freedom of Form: OnScreen
18 construction allows a wide variety of signage/display
19 forms. One example is a vertical axis cylindrical
20 display viewed from the inside and/or the outside and
21 with varying degree of array transparency determined by
22 design.

23 6. Shop Or Site Fabrication: The light
24 weight and flexible nature of the OnScreen array
25 coupled with the mechanism of flexible local linkage
26 allows for shop fabrication of large area arrays.

1 7. Pixel Level Voltage Reduction: Pixel
2 'on-board' reduction allows higher array supply
3 voltages and thereby lower current levels and reduced
4 self-heating of array wiring and/or reduced wire cross-
5 sectional area.

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